Waste Crate and Container Imaging Using the Vehicle and Cargo Inspection System

Deactivation and Decommissioning Focus Area

Prepared for

U.S. Department of Energy

Office of Environmental Management

Office of Science and Technology

March 2000

INNOVATIVE TECHNOLOGY
Summary Report

Waste Crate and Container Imaging Using the Vehicle and Cargo Inspection System

OST/TMS ID 2912
LA-UR/LA-CP99-5934

Deactivation and Decommissioning Focus Area

Demonstrated at
Los Alamos National Laboratory
Los Alamos, New Mexico

INNOVATIVE TECHNOLOGY
Summary Report

Purpose of this document

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine whether a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available on the OST Web site at http://ost.em.doe.gov under "Publications."

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SECTION 1
SUMMARY

Technology Summary

Problem

The United States Department of Energy (DOE) continually seeks safer and more cost-effective remediation technologies for use in the decontamination and decommissioning (D&D) of nuclear facilities. To this end, the Deactivation and Decommissioning Focus Area (DDFA) of the DOE's Office of Science and Technology sponsors Large-Scale Demonstration and Deployment Projects (LSDDPs) in which developers and vendors of improved or innovative technologies showcase products that are potentially beneficial to the DOE's projects and to others in the D&D community. Benefits sought include decreased health and safety risks to personnel and the environment, increased productivity, and decreased cost of operation.

The LANL inventory of low-level transuranic (TRU) waste includes over 600 large fiberglass reinforced plywood (FRP) crates containing waste such as gloveboxes, tanks, furnaces, ductwork, Pu-238 coffins, filter media, and contaminated soil. Approximately 2400 cubic meters of this waste is currently in storage at the Los Alamos solid waste disposal area, TA-54, and another 3000 cubic meters will be generated as LANL facilities are decommissioned. All of these wastes will be processed in the Los Alamos Decontamination and Volume Reduction System (DVRS). The DVRS will characterize the boxes, decontaminate to low-level waste limits, volume reduce in a baler and then dispose on site in TA-54. The TRU fractions will be processed to meet the Waste Acceptance Criteria of the Waste Isolation Pilot Plant (WIPP) by removal of prohibited items, repackaging into appropriate sized drums or boxes and other applicable WIPP requirements. The constituents of each crate were partially documented during crate loading; however, a detailed picture of the crate contents would greatly facilitate crate dismantlement and contents handling.

The overall objective of this demonstration was to determine whether the Vehicle and Cargo Inspection System (VACIS™), developed by Science Applications International Corporation (SAIC), is an effective enabling technology for the non-invasive inspection of the waste crates and other containers. The image of container contents provided by VACIS™, along with a radiation survey of each container, will allow workers to plan the safest and most efficient approach to open each container and process its contents through DVRS. The DVRS baseline process did not include radiography of the crates because it was not known to be possible.

How It Works

SAIC's VACIS™ is a gamma-ray imaging system used to non-intrusively inspect trucks, cargo containers, railcars and passenger vehicles. Stationary VACIS™ units have been used by the United States Customs Service since 1997 to inspect cargo trucks for drugs and other contraband at US border crossings. The early success of VACIS™ has expanded its use to scanning moving vehicles and railcars.

In the mobile unit tested at LANL, the source and detector are mounted on a boom truck, with the source positioned in a shielded box at the end of the boom and the detector mounted on the truck. As the waste container passes between the source and detector, the VACIS™ unit's on-board computer constructs a composite image of the contents.

Figure 1 Mobile VACIS™ Unit

Demonstration Summary

The Integrated Contractor Team (ICT) of the Los Alamos Large Scale Demonstration and Deployment Project demonstrated the mobile VACIS™ unit in June 1999 as part of the Large Scale Demonstration and Deployment Project, funded by the U.S. Department of Energy's Deactivation and Decontamination Focus Area at the National Energy Technology Laboratory. The demonstration took place within a temporary structure at the LANL Solid Waste Operations Area, Technical Area 54, Area G. Figure 1 shows the VACIS™ unit used for the demonstration. Waste containers consisting of fiberglass reinforced plywood (FRP) crates and standard waste boxes (SWBs) were loaded onto flatbed trucks, driven to the demonstration area and imaged using the VACIS™ mobile unit. Once positioned, the driver exited the truck and the VACIS™ unit drove along the flatbed, compiling the image. Images were reviewed in near real-time and were recorded on disk. All phases of the operation were closely monitored by LANL radiation control technicians. Personnel from the US Army's Thunder Mountain Test and Evaluation Center (TMEC) from Fort Huachuca, AZ operated the VACIS™, along with representatives from the unit's developer, Science Applications International Corporation (SAIC). The demonstration was supervised by LANL Solid Waste Operations staff.

The VACIS™ mobile unit provided quality images of the crate and waste container contents in which items such as gloveboxes, equipment, debris and equipment inside gloveboxes, and filter media were clearly visible. Once the flatbed truck was positioned, an image was obtained in less than 30 seconds. Images can be enhanced using a tool box of image processing tools, such as negative imaging, false color, and shading control.

The demonstration met or exceeded expectations for enhanced understanding of the waste container contents in support of opening and classification of contents. Images produced by VACIS will enhance both the container processing planning and worker safety during the container opening process. A cost savings is expected from improved planning that ensures the appropriate materials and equipment will be in-place as the container opening begins. Schedule impact from unknowns encountered during processing will be minimized. Worker safety will be enhanced by the improved knowledge of the items in the crates and knowledge of the best place to cut into the crates.

A cost estimate of the cost of using VACIS was conducted using a basis of 100 containers. With this basis, the unit cost for VACIS deployment was $630 per container.

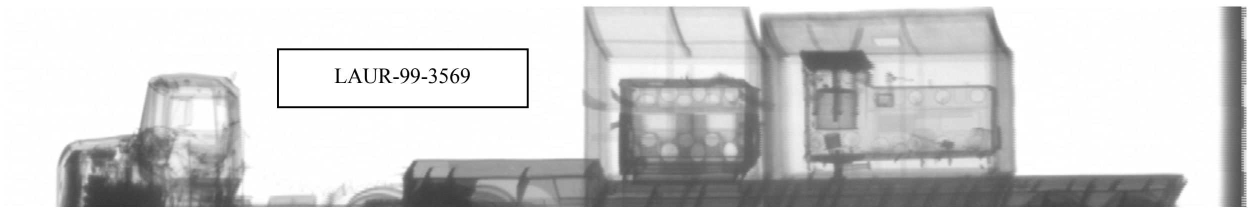

Figure 2 VACIS™ Image of two crates on a flatbed trailer

As shown in Figure 2 above, the image clearly reveals the crate contents (gloveboxes and equipment in the second glovebox). Based on this successful imaging, LANL intends to image all 600 crates and containers in inventory.

Benefits:

- Provides non-invasive images of large crates and waste containers
- Capable of scanning up to 40 crates or containers per hour
- Guides opening of contaminated contents
- Provides inventory reconciliation/confirmation
- Facilitates crate selection and scheduling for the DVRS process
- Improves worker safety during opening of waste packages

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Other

All published Innovative Technology Summary Reports are available on the OST Web site at http://ost.em.doe.gov under "Publications." The Technology Management System (TMS), also available through the OST Web site, provides information about OST programs, technologies, and problems. The OST reference number for the VACIS demonstration is #2912.

The Los Alamos LSDDP website address is: http://www-emtd.lanl.gov/LSDDP/DDtech.html.

SECTION 2
TECHNOLOGY DESCRIPTION

Overall Process Definition

The overall objective of the demonstration was evaluation of VACIS™ for its ability to characterize the contents of the FRP crates and other waste container types at LANL. If successful, the cost and risk of the subsequent waste container processing would be greatly enhanced. Specifically, the safety of crate opening would be enhanced by knowledge of the spatial orientation of the metallic objects. In addition, identification of glove boxes with lead shielding will avoid the opening of a crate of mixed waste without requisite preparations.

The VACIS™ mobile unit demonstrated at Los Alamos National Laboratory's TA-54 consisted of a truck mounted linear detector and a radiation source deployed on a boom arm. One or two waste containers were loaded onto flatbed trucks and driven into position for imaging by the VACIS™ unit. The driver exited the flatbed truck and the VACIS™ unit drove along the length of the flatbed to image the container and contents. Following the scan, an image appeared on the screen of the VACIS™ unit's on-board computer. Operators within the VACIS™ unit can store or print the image. Various image processing tools such as gray-scale spectrum adjustment, shading, and false color are also available. The complete scan of the vehicle with all the containers took less than 30 seconds.

The demonstration took place in a large (100 by 300 feet) temporary structure equipped with rollup doors for flatbed truck access at either end. The structure allowed for the control of access in accordance with the radiation control plan developed for the demonstration.

System Operation

The VACIS™ unit used for this LSDDP demonstration was a prototype unit designed and built by Science Applications International Corporation and was under acceptance testing and evaluation by the US Army Thunder Mountain Evaluation Center (TMEC) in Fort Huachuca, Arizona. The VACIS unit was operated by TMEC personnel as a part of their acceptance testing.

The VACIS™ unit uses a 1.6 Curie (Ci) collimated source (Cesium-137) aimed at a linear detector. As the waste container passes between the source and detector, a composite image of the contents is constructed from the linear image by the VACIS™ unit's on-board computer. The maximum rate of movement of either the container or the VACIS™ unit is 8 inches per second or approximately 40 feet per minute. The minimum image height above the ground for this VACIS™ unit was 2 feet. For this reason, flatbed trucks were used to elevate the containers and to transport them from the container storage area to the imaging area. Each container was given a unique ID number, which was also used to label the corresponding VACIS™ image. Other operational parameters are shown in Table 1.

Operational safety concerns with the VACIS™ unit included potential radiation hazards associated with the gamma ray imaging. To address these concerns, radiation exposure data was collected from all site workers present at the demonstration. In addition, the LANL Radiation Work Permit included trial run radiation monitoring.

Table 1. Operational parameters and conditions of the VACIS™ demonstration

Operational Parameter	Los Alamos Application
Work Area Location	Los Alamos National Laboratory, TA 54
Work Area Description	Large 100x300 feet indoor area with drive through capability
Work Area Hazards	• Movement of vehicles • Potential radiation hazard between source and detector during operation • Loading and unloading of large crates
Waste Container Size	• Smallest was approximately 3 ft x 3 ft x 4 ft • Largest was approximately 14 ft x 9 ft x 8 ft and weighed 5000 pounds
Work Crew	• Two technicians inside the VACIS™ unit, • Third technician to position and direct the flatbed truck • One forklift operator • Two flatbed truck drivers • Two radiation control technicians
Additional Support Personnel	Full-time demonstration data taker
Training	• Rad Worker II training required for VACIS™ operators • Site specific training on evacuation procedures
Equipment Design Purpose	Non-invasive imaging of trucks and cargo containers
Dimension	Truck mounted unit, approximately 7 feet wide by 25 feet long
Personal Protective Equipment	• Safety glasses • Steel toed boots • Hardhats near forklift operations • TLD, ALOKA and alarming dosimeters based on LANL requirements
Utilities	120V power supply required for remote video monitoring All VACIS™ power requirements were supplied by an on-board generator

SECTION 3
PERFORMANCE

Demonstration Plan

The mobile VACIS™ unit was driven to LANL by the TMEC technicians. The imaging source was shipped separately by overnight carrier because a license for on-board transport of the source had not been received by the time of the demonstration.

Prior to the demonstration, a list of candidate FRP crates and standard waste boxes (SWBs) was developed for the VACIS™ imaging. The list purposely included FRP crates of varying size and different content descriptions. The candidate FRP crates and containers were also evaluated for integrity to ensure that they would withstand loading and unloading.

Waste containers were stored in a fabric dome approximately one-quarter mile from the VACIS™ imaging location. A high capacity forklift was used to load the containers onto the flatbed trucks. A maximum of two containers were loaded per truck. Radiation control technicians (RCTs) were present to scan the containers during loading and offloading. The loaded trucks were driven to the VACIS™ location, positioned, parked, and scanned by the VACIS™ unit. Each scan was completed within 30 seconds.

Prior to the start of scanning, LANL RCTs collected radiation data with the radiation source shutter open (imaging configuration) to establish the radiation control access area. Measurements were taken at a variety of angles and distances.

As part of the demonstration, the time for imaging of the waste containers was recorded, including time required for loading and unloading. Other time data recorded included mobilization, daily preparation time, plans and permits meetings, and demobilization. Labor requirements were also recorded for these tasks. Other recorded data included radiation exposure, and costs for labor, materials and equipment. Labor costs included demonstration personnel, support personnel, and labor costs for plans and permits. Images from the VACIS™ demonstration were saved and printed for further evaluation as to clarity, resolution of contents and overall usefulness.

The overall test objective of the VACIS™ demonstration was to assess the feasibility and utility of VACIS™ imaging of LANL FRP crates. Specific objectives were to determine:

- Ease of technology implementation
- Health and safety issues associated with technology deployment
- Object resolution of the method, including ability to resolve superimposed objects
- Identify lead-shielded objects
- Cost-effectiveness and risk reduction offered by the technology
- Decontamination ease and maintenance costs
- Identify VACIS™ system configuration that best supports the LANL operations requirements.

Figure 3 VACIS™ Unit at the LANL Demonstration Site

Results

Over the two day test period, images of approximately 40 FRP crates and other waste containers were obtained. These images clearly showed the contents of each. Comparison of the image with the inventory description will greatly enhance inventory knowledge. Knowledge of the orientation of the objects within the FRP crate as well as any equipment inside the gloveboxes will also enhance container disassembly, processing, and size reduction. Lead shielded objects appear opaque on the VACIS™ image, allowing the user to ascertain the presence of lead. Knowledge of lead contents is critical for mixed waste classification and scheduling of crate opening in the DVRS process.

Each of the test objectives is addressed individually below:

- **Ease of technology implementation**
  Implementation of the technology was straightforward. The VACIS™ unit itself requires only that the containers for imaging be elevated a minimum of 2-feet off the ground to allow for imaging of the entire vertical length. Flatbed trucks were used to elevate the containers. Imaging of the containers and vehicle, once positioned on the flatbeds, was completed in less than 30 seconds.

- **Health and safety issues associated with technology deployment**
  Based on radiation measurements conducted at the site of the demonstration, the VACIS™ unit poses negligible incremental exposure for workers and the surroundings.

- **Object resolution of the method, including ability to resolve superimposed objects as well as lead-shielded objects.**
  The method shows excellent large object resolution, i.e. gloveboxes, equipment inside gloveboxes, filters, and hardware were clearly visible as such. Small object and low density object resolution was less successful. For example, known objects such as tools, a tire, a fire extinguisher and a gallon jug of water that were placed in a relatively small (3-foot by 4-foot by 2-foot deep) container yielded an indistinct image. Small container resolution could be improved by better configuring of the source and detector, which in principle is possible with the VACIS™ unit. This improved imaging is subject to the limits imposed by the source to detector distance, which is a function of the source boom minimum length. Lead shielded objects were evident as definitive dark areas around the gloveports in the gloveboxes.

- **Cost-effectiveness and risk reduction offered by the technology**
  As presented in Section 5, the VACIS™ technology can be implemented at a per container cost of about $630, assuming one hundred crates are analyzed. Larger number of containers or expedited container handling procedures will further reduce the unit cost. The VACIS™ yielded container images that were immediately useful with respect to inventory reconciliation and configuration of the contents. This data will enhance work planning and subsequently the worker safety during opening and size reduction of crate contents. One of the demonstration objectives was identification of lead shielding. The VACIS™ images provide a clear identification of lead shielded gloveboxes which will not be opened until the mixed waste processing procedures are well established. This cost avoidance also supports the cost effectiveness of VACIS™.

- **Decontamination ease and maintenance costs**
  The VACIS™ unit did not require decontamination after the demonstration. It does not make direct contact with the package to be imaged, rather a boom arm with the source is extended around the unit without making contact (see Figure 3). There is the potential for contamination associated with the movement of the crates and containers on and off the flatbed trailers if the package integrity is not sound. LANL waste operations personnel are interested in future evaluation of VACIS™ for in-place imaging of these crates.

  Maintenance costs of the VACIS™ unit are minimal, with most of the maintenance of ownership entailing VACIS™ vehicle maintenance.

- **Identify the VACIS™ system configuration that best supports the LANL operations requirements.**
  The imaging procedure used at the LANL demonstration involved loading the waste containers onto flatbed trucks and imaging the trucks and cargo using the VACIS™ system. This proved to be a good operational procedure for LANL. The VACIS™ unit's rate of imaging far exceeded the rate at which waste containers could be loaded onto flatbed trucks and offloaded. The bottleneck for the imaging process was clearly the handling of the large FRP crates, including positioning for loading, loading onto flatbeds and subsequent offloading and replacement into storage. A future imaging operation might improve on these logistics and reduce per crate costs.

SAIC personnel have stated that design options exist for improving the penetrating power of the source or improving the image resolution for DOE applications.

Examples of VACIS™ images are shown below. Figure 4 shows three gloveboxes within a crate. Figure 5 shows two crates on a flatbed trailer. The first crate in Figure 5 contains two gloveboxes that have been built around machine tools. The second crate contains a glovebox with lead shielding. Figure 6 shows two crates containing piping.

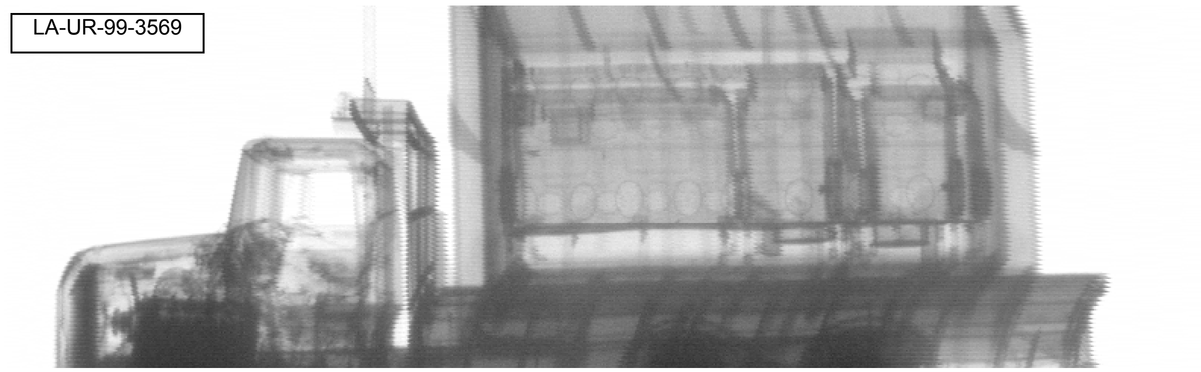


Figure 4 VACIS™ Image of Gloveboxes within an FRP Crate

Figure 5 VACIS™ Image of Two Crates Containing Gloveboxes with Machine Tools and a Shielded Glovebox

Figure 6 VACIS™ Image of Crates Containing Piping

SECTION 4
TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Competing Technologies

The VACIS™ technology was selected for demonstration by the Los Alamos ICT to address a need identified by the Los Alamos Solid Waste Operations staff during project meetings with the LSDDP Technology Selection Committee. The baseline DVRS process did not include plans/technologies for radiography of the oversized crates as it was not known that a technology existed. It was considered a "technical need" as improved knowledge of crate and container contents and orientation would allow the operations staff to better understand the expected hazards and the safest location for cutting and opening the packages. As a secondary benefit, it provides the Los Alamos management better information for selecting the first containers to be opened in the process, and thereby avoids opening mixed waste containers early in the campaign.

Systems for x-ray radiography of DOE's Standard Waste Boxes are in testing at several DOE sites. Mobile Characterization Services (MCS) offers a service for Standard Waste Boxes using systems designed by VJ Technologies. However, many LANL oversized crates are too large for these systems. As a second option, two manufacturers of x-ray units for trucks and cargo containers were identified. Personnel from the Thunder Mountain Evaluation Center (TMEC) were familiar with these technologies. The TMEC personnel recommended that these available truck x-ray units do not have the penetrating power necessary to see into the gloveboxes. The TMEC personnel did however, recommend that the prototype transportable VACIS™ system would meet the project objectives.

Technology Applicability

The VACIS™ technology has direct application for the imaging of large waste containers whose contents may be uncertain. It also is useful for determining the orientation of objects within the waste container prior to opening of the containers. The method is less useful for scanning the contents of smaller containers such as drums.

Several stationary VACIS™ units are in service at US ports and border crossings to survey for contraband and for freight manifest reconciliation. The US Customs Service has since ordered 11 mobile VACIS™ units for deployment at US border crossings. The VACIS™ unit may also have potential for use in security enhancement at DOE facilities.

Patents/Commercialization/Sponsor

The VACIS™ is manufactured and marketed for sale by SAIC. Several stationary VACIS™ units are in service across the US. The mobile VACIS™ unit used for this demonstration was a prototype. The unit was operated by personnel from the US Army's Thunder Mountain Test and Evaluation Center as a part of their evaluation of the prototype. Various SAIC patents are pending on the VACIS™ unit.

SECTION 5
COST

Methodology

The objective of the cost analysis was to provide interested parties with a cost estimate for implementation of the VACIS™ technology on a production scale at a DOE site. The actual demonstration costs incurred at LANL formed the basis of the cost estimate. To approach realistic implementation costs, additional assumptions were invoked regarding the greater efficiency of a production, rather than demonstration, setting.

Note that no costs of the competing technologies are calculated in this report as VACIS™ is an enabling technology and there are no comparable data from those technologies. As an enabling technology, VACIS™ enhances the safety and operations of DVRS above the baseline. No costs for characterization of this type were included in the DVRS plans.

Key assumptions for the cost estimate are listed below. Other assumptions and details on the cost analysis are presented in Appendix C.

1. A DOE site, such as LANL, will purchase a mobile VACIS™ unit from SAIC and lease it back to a site on an hourly basis ($100/hr). This hourly price was calculated using an Office of Management and Budget (OMB) circular No. A-94 for computation of equipment rates for government owned equipment. Cost factors include ownership costs, operating costs, fuel and other consumables and repairs and maintenance. A purchase price (GSA rate) of $955,000 was quoted by SAIC.

2. A VACIS™ operating crew will be formed and dedicated to the unit. The crew of three persons will mobilize from the VACIS™ provider site (assumed for estimation purposes to be LANL).

3. Equipment to stage the waste containers (forklift and two flatbed trucks) and a crew of three equipment operators were assumed to be available at the DOE site at prevailing local equipment and labor rates.

4. Other labor provided by the DOE site include: a site coordinator, site health physics supervisor, and site radiation control technicians. The site coordinator and site health physics supervisor are senior staff who will manage the project at the DOE site, including preparation of plans, permits, and approvals.

5. Fully-burdened labor rates for LANL personnel were used in the estimate.

6. No overhead factors were applied to other direct costs.

7. The operating protocol was assumed to consist of a) loading of one to two containers on to a flatbed truck, b) driving the flatbed truck to the VACIS™ imaging area, c) parking of the flatbed truck and scanning of the truck and crates using the VACIS™ unit, d) return of the flatbed truck, offloading and loading of a new container. A production rate of 20 containers per day (100 containers per week) was based on the demonstration's experience with processing of crates.

Cost Analysis

To develop an estimate for implementation, a basis of 100 containers was chosen. Activities were grouped under higher level work titles per the work breakdown structure (WBS) shown in the Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary (HTRW RA WBS) (U.S. Army Corps of Engineers 1996).

Figure 7 provides a summary of the implementation costs assuming the 100 container basis. The total estimated cost for analysis of 100 containers is approximately $63,400, giving a unit cost of $634 per container. The unit cost decreases if more crates than 100 are analyzed per mobilization as shown in Figure 8.

Cost Conclusions

The cost estimate provides a reasonable cost for implementation of VACIS™ imaging at a DOE site. Using the demonstration costs as a basis, costs were developed for mobilization and planning/permits, VACIS™ imaging, decontamination and equipment release, and demobilization. VACIS™ imaging costs were scaled to a basis of 100 crates and waste containers, representing one week of imaging. Candidate sites may use this basis to scale up to their anticipated costs by considering the number of crates or containers for scanning.

Preparation/permitting costs were a significant component of the total project cost. There were no learning curve efficiencies attributed to these costs because of the likelihood that each DOE site will have permitting requirements that were similar in scope to those required by LANL for the demonstration. An exception might occur if the VACIS™ unit was to make more than one visit to a site. In that case, plans and permits may only require updating.

Figure 7 summarizes the results of the cost analysis. The bars indicate the cost of the individual activities used to calculate a total cost and the line sums the costs. Using a basis of 100 containers, the unit cost for imaging was $630 each. This per-container cost offers the potential of a positive cost-benefit in light of the enhancements in health and safety and container opening efficiency.

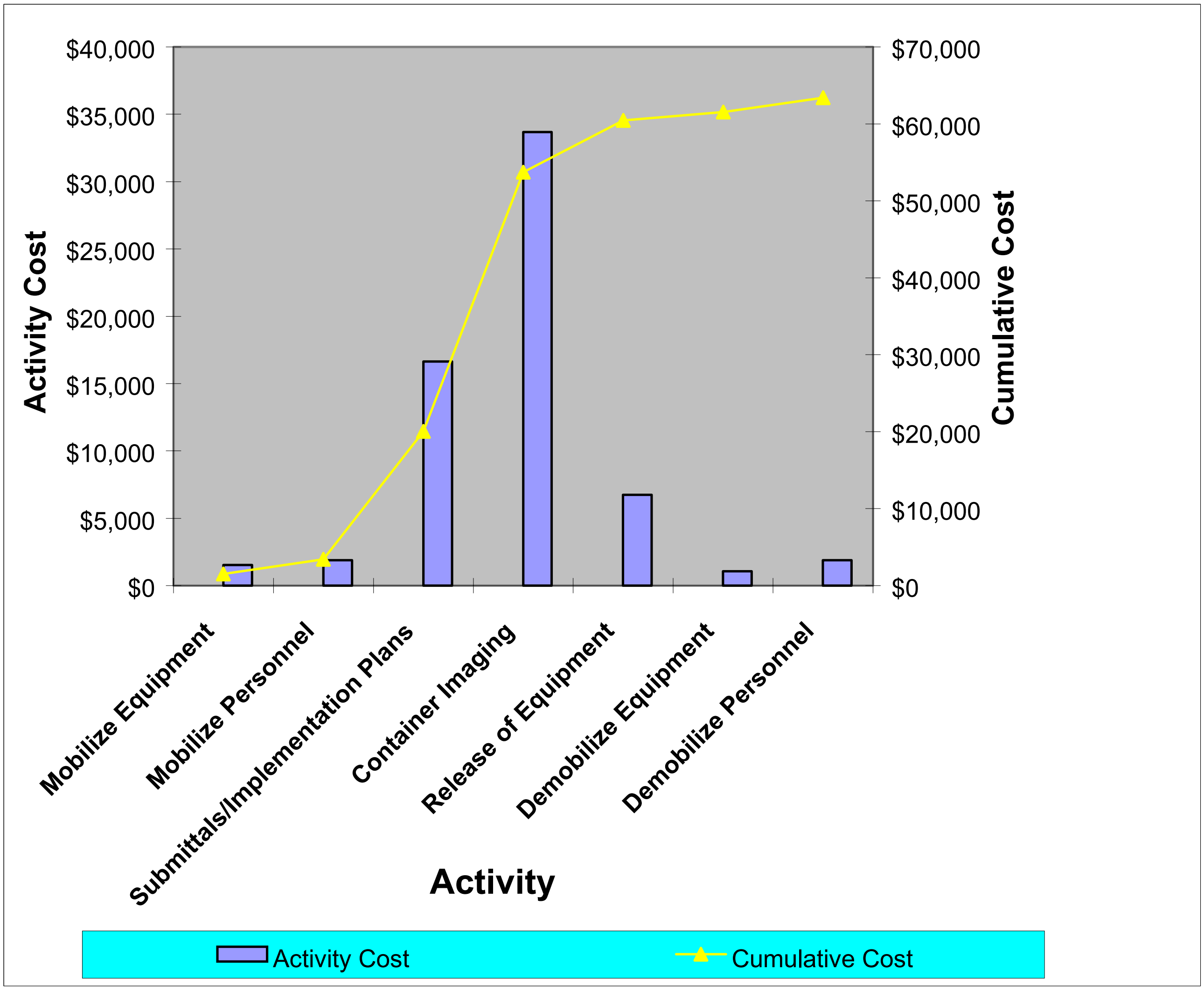


Figure 7 Summary of Implementation Costs for VACIS™ Imaging of 100 Containers

Figure 8 shows the dependency of the unit container cost on the number of containers to be imaged. As the number of containers becomes large the fixed costs of mobilization, permitting, and demobilization are diluted and the unit cost drops to less than $400. Note also that if a large number of crates or packages were to be imaged, expedited crate management could further reduce costs.

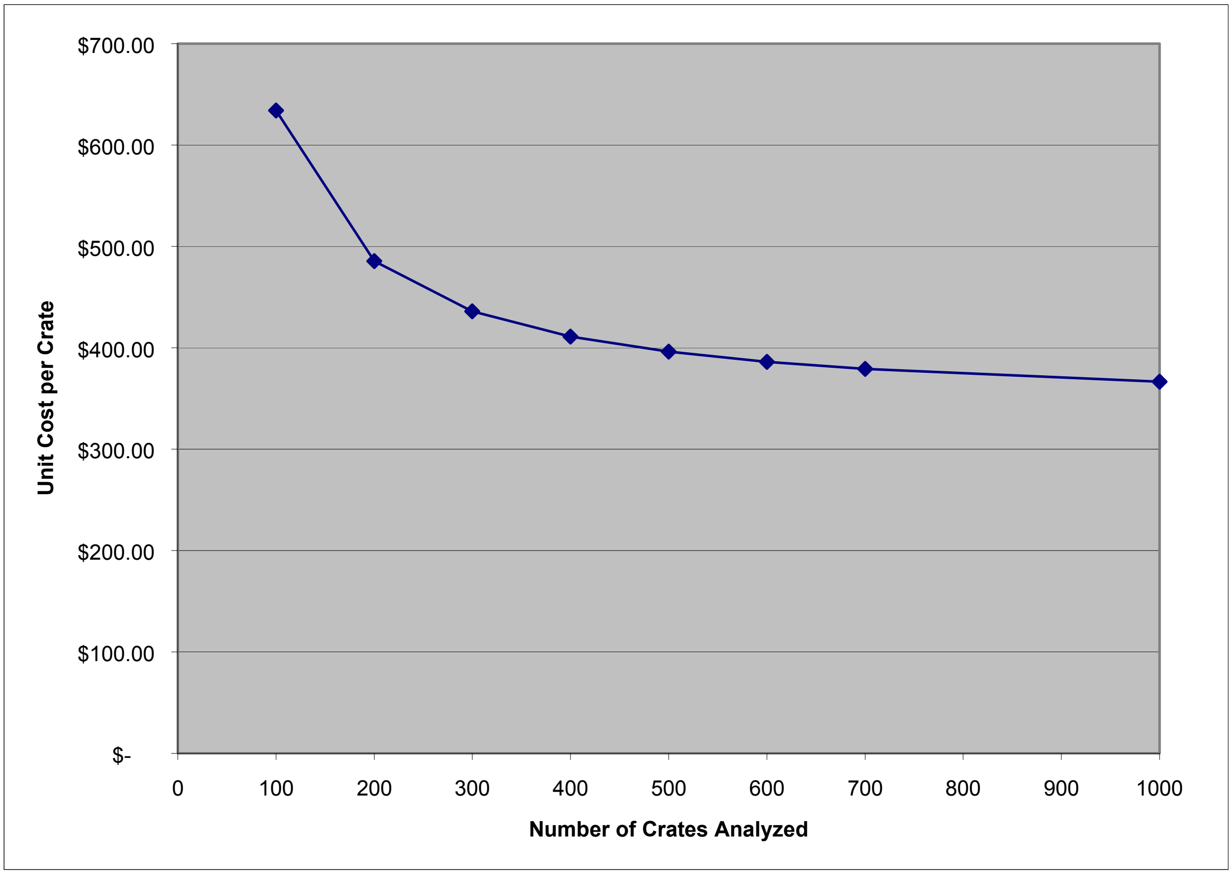


Figure 8 Total Container Costs for VACIS™ Imaging

SECTION 6
REGULATORY AND POLICY ISSUES

Regulatory Considerations

Shipment of the radiation source poses the only regulatory issue attendant with use of the VACIS™ technology. Currently, the source is licensed in only a few states for on-road shipment within the VACIS™ truck. Overnight shipment is readily available throughout the US.

Safety, Risks, Benefits, and Community Reaction

Worker Safety
Operators of the VACIS™ unit must be trained in the proper procedures for source handling, image gathering and image analysis, and VACIS™ vehicle operations. The VACIS™ unit used a collimated source which minimized radiation exposure. Radiation monitoring of the workers and attendees at the demonstration showed negligible incremental radiation exposure from the VACIS™ unit.

Manipulation of large waste containers, including forklift operations, backing and positioning of vehicles and selection and return of crates to inventory poses potential hazards for workers.

For workers involved in the opening of the waste containers and the resizing of the contents, worker safety can clearly be enhanced by contents images provided by the VACIS™ system. An image of the contents allows the worker to better position initial cuts into the container, and allows the subsequent removal and resizing operations to be tailored to the contents of the package.

Community Safety
Community safety is not adversely affected by operation of the VACIS™ unit. The VACIS™ will not significantly increase the background radiation in an area. Transportation of the source by common carrier also poses little community risk because the source is secured for shipment inside an approved container.

Environmental Impact
There is no negative environmental impact and a potential positive impact to use of the VACIS™ unit. The positive impact consists of the health and safety provisions that can be implemented as a result of the knowledge of specific container contents. This allows environmental containment controls to be designed appropriately.

Socioeconomic Impacts and Community Reaction
There are no socio-economic impacts associated with the VACIS™ unit. Community reaction is likely to be positive given the enhancements to both worker and environmental safety that are offered by the VACIS™ unit.

SECTION 7
LESSONS LEARNED

Implementation Considerations

The VACIS™ demonstration at LANL yielded several lessons learned including:

- Site-specific health and safety requirements, including daily radiation monitoring, source mobilization and demobilization and health and safety meetings can comprise 25 to 30 percent of the available operational time.
- Logistics in handling of the large FRP crates are important for efficient VACIS™ imaging. The VACIS™ unit can image the crates and containers at a much faster rate than they can be positioned. If possible, the pre-positioning of the containers on an elevated surface (at least 2 feet above the ground) would greatly enhance the utilization of the mobile VACIS™. In such a scenario, a row of elevated containers can be expeditiously scanned by driving the VACIS™ unit along the row of containers.
- Adequate time should be budgeted for site-specific procedure approvals.

Technology Limitations and Needs for Future Development

The Los Alamos demonstration conclusively proved that VACIS™ will accomplish the task it was designed for, radiography of trucks and rail cars. It provides DOE good information on the size, orientation, and metallic thickness of large crated metal objects. Additionally, it can radiograph at a very fast rate and a single unit could address the entire DOE packaged waste problem.

For the DOE application, the only shortcoming is the technology's inability to clearly characterize homogeneous waste-type contents of packages. Since it was designed for trucks, the fact that the system cannot radiograph within 2 feet of the ground is not a problem. However, for DOE's containerized waste problem the ability to characterize a container standing on the ground would avoid the handling necessary to get the packages on to a truck or frame.

SAIC personnel indicate that higher power sources are available for penetrating more than 2.5 inches of steel or homogeneous materials. In addition the detector array can be reconfigured for specific applications.

Technology Selection Considerations

Considerations for selection of this technology include:

- Adequate area for the positioning of the large waste containers, including the requirement that the containers be elevated a minimum of 2 feet above the ground
- Resolution is difficult when many objects are superimposed. The technology works best when the number of objects within a waste container is limited
- To take advantage of the high throughput capacity of the VACIS™, the logistics of containers positioning should be arranged in advance, including possible pre-positioning. This would optimize the VACIS™ imaging cost.
- The VACIS™ resolution power does not support the identification of small or thin items such as aluminum shovels and superimposed small objects such as hand tools.

APPENDIX A
REFERENCES

IT Corporation, 1999, Project Specific Test Plan for the Field Demonstration of the Mobile Vehicle and Cargo Inspection System (VACIS^{TM})

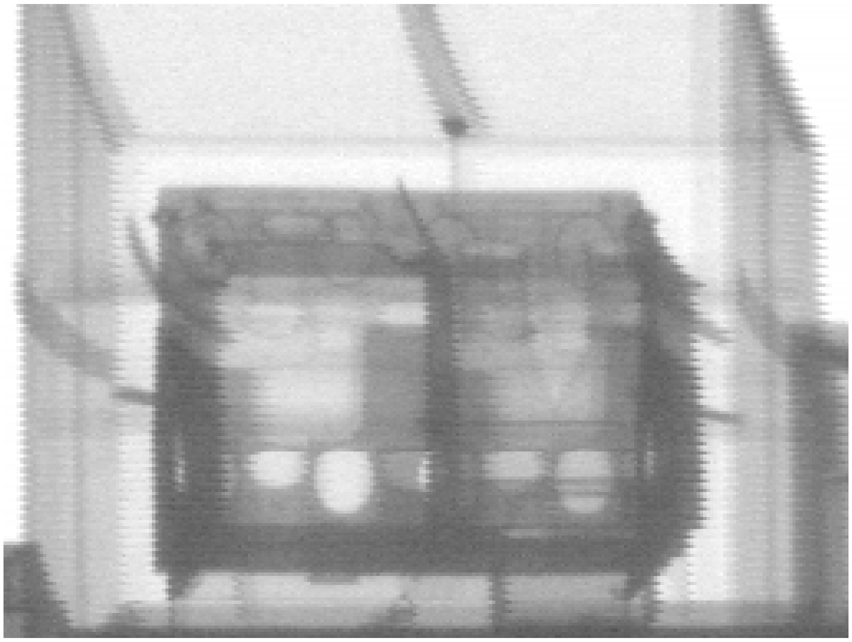
U.S. Army Corps of Engineers, 1996, Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary

APPENDIX B

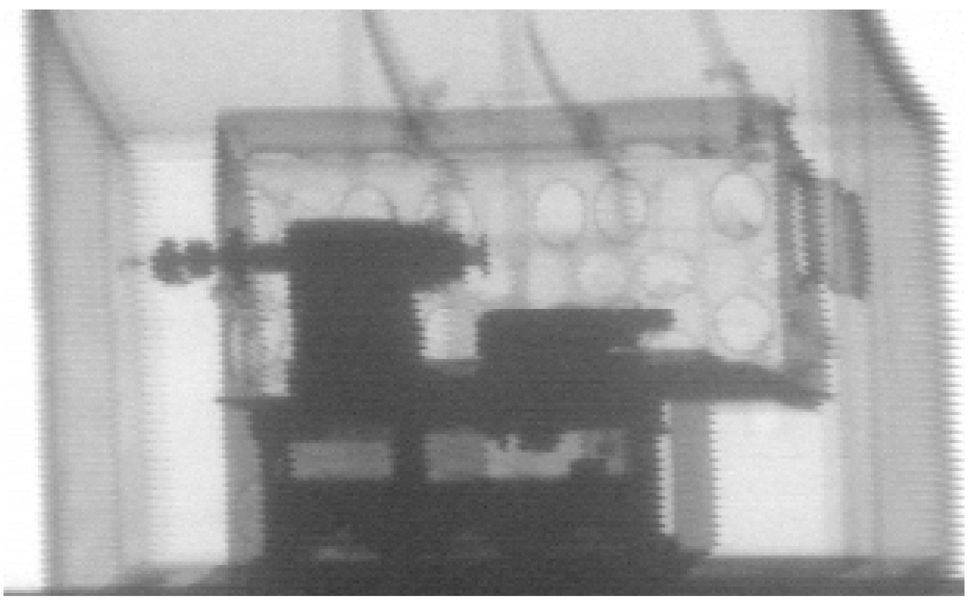
Comparison of Contents Photos with VACIS™ Images

Several photographs of actual crate contents were located in LANL archives. This appendix presents two such photographs and the corresponding VACIS™ images.

Glovebox positioned in crate prior to closing and corresponding VACIS™ image



Glovebox with mill prior to crating and corresponding VACIS™ image.



APPENDIX C
Cost Details

Basis of Estimated Cost

The activity titles shown in this cost analysis for implementation were derived from observation of the work performed and from a reasonable estimate of the level of effort required for implementation at other DOE sites. In the estimate the activities are grouped under higher level work titles according to the work breakdown structure shown in the Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary (HTRW RA WBS) (U.S. Army Corps of Engineers 1996). The HTRW RA WBS, developed by an interagency group, and is used in this analysis to provide consistency with the established national standards. The costs shown in this analysis are computed form observed duration and hourly rates for the crew and equipment.

Activity Descriptions

The scope of each WBS element, computation of production rates, and assumptions (if any) for each work activity are described in this section.

Mobilization and Preparatory Work (WBS 33.1.01)
Mobilization of Equipment – It was assumed that the VACIS™ unit will mobilize from the Los Alamos National Laboratory to another DOE site that will need to have containers analyzed. An average one-way distance for mobilization was assumed to be 500 miles. Mobilization consists of transporting both the VACIS equipment, which is mounted on a flatbed truck, and a support pickup. All other equipment such as flatbed trailers and forklifts were assumed to be rental equipment from a local source. It was estimated that equipment can be prepared for mobilization in 2 hours. Mobilizing to another DOE site was assumed to require 8 hours.

Mobilization of Personnel – It was assumed that the VACIS™ crew will mobilize from Los Alamos, New Mexico. Other equipment operators such as fork lift and flatbed operators were assumed to be local hires. Mobilization was assumed to include 1 hour of site-specific facility safety training.

Submittals/Implementation Plans – Plans and permits were assumed to be complete prior to the start of work. It was estimated that VACIS™ Operators and Site Equipment Operators will require 8 hours to provide readiness review support for attainment of final approval to proceed. For the LANL VACIS™ demonstration, this review support took the form of test runs with and without the cesium source. It was estimated that the Site Health Physics Supervisor and a Site Health Physics staff person will each require 40 hours to develop plans and permits. The Site Coordinator, who will manage the operation at the site, will require 80 hours to prepare for the work and develop the plans and permits. A Site Radiation Control Technician will require 9 hours for plan/permit support.

Monitoring, Sampling and Testing (WBS 33.1.02)
Waste Container Imaging - Based on the LANL VACIS™ demonstration, it was assumed that Site Equipment Operators will load the containers to be imaged onto flatbed trucks using a forklift, after which the flatbed truck will be driven to the imaging site for imaging by the VACIS™. The VACIS™ unit will image the container by driving along the length of the parked flatbed truck. After obtaining the image, a Site Equipment Operator will drive the flatbed truck to the container storage area for unloading. This process is then repeated for additional containers. Due to logistical constraints such as space required to stage containers for loading and return to storage, a reasonable rate of 20 containers per day (8 hour period) was achieved and is estimated for future implementation. For this estimate, a processing rate of 20 containers per day and 100 containers per week was assumed.

Equipment Decontamination and Release – Smear sampling of all offsite equipment was required prior to release. Based on this demonstration, 8 hours was required for equipment sampling and release.

Demobilization (WBS 33.1.21)

Demobilization of Equipment and Personnel – It was assumed that the VACIS™ equipment and operators will demobilize a distance of 500 miles. Demobilization will consist of transport of the VACIS™ unit and an equipment truck. It was estimated that the VACIS™ equipment can be prepared for demobilization in 2 hours and demobilize in 8 hours.

Cost Estimate Details

The cost analysis details are summarized in Figure B-1. The table breaks out each member of the crew, each labor rate, each piece of equipment used, each equipment rate, each activity duration, and all production rates so that site-specific differences in these items can be identified and a site-specific cost estimate can be developed.

WBS Activity	Labor	Equipment	Other Costs	Unit of Measure	Unit Cost	Quantity	Subtotals
Mobilization and Preparatory Work (WBS 33.1.01)							$ 20,050
Mobilize Equipment							*$ 1,533*
	VACIS Super			hour	$ 61	2	$ 123
	VACIS Tech 1			hour	$ 48	2	$ 97
	VACIS Tech 2			hour	$ 48	2	$ 97
		VACIS Unit		hour	$ 100	10	$ 1,001
		1/2T-Pickup		hour	$ 7	10	$ 65
		Ship Source		round trip	$ 150	1	$ 150
Mobilize Personnel							*$ 1,882*
	VACIS Super			hour	$ 61	10	$ 613
	VACIS Tech 1			hour	$ 48	10	$ 485
	VACIS Tech 2			hour	$ 48	10	$ 485
			Per diem	day	$ 100	3	$ 300
Submittals/Implementation Plans							*$ 16,636*
	VACIS Super			hour	$ 61	8	$ 490
	VACIS Tech 1			hour	$ 48	8	$ 388
	VACIS Tech 2			hour	$ 48	8	$ 388
			Per diem	day	$ 100	3	$ 300
	Site Health Physics Super.			hour	$ 80	40	$ 3,218
	Site H&S Staff			hour	$ 71	40	$ 2,848
	Site Coordinator			hour	$ 90	80	$ 7,170
	Site Radiation Control Tech.			hour	$ 48	9	$ 436
	Site Equipment Operators			hour	$ 58	24	$ 1,398
Monitoring, Sampling & Testing (WBS 33.1.02)							$ 33,672
Container Imaging							*$ 33,672*
	VACIS Super			hour	$ 61	40	$ 2,450
	VACIS Tech 1			hour	$ 48	40	$ 1,938
	VACIS Tech 2			hour	$ 48	40	$ 1,938
			Per diem	day	$ 100	15	$ 1,500
	Site Health Physics Super.			hour	$ 80	40	$ 3,218
	Site H&S Staff			hour	$ 71	40	$ 2,848
	Site Coordinator			hour	$ 90	40	$ 3,585
	Site Radiation Control Tech.			hour	$ 48	40	$ 1,938
	Site Equipment Operators			hour	$ 58	120	$ 6,990
		VACIS Unit		hour	$ 100	40	$ 4,005
		Forklift - 8 ton		hour	$ 38	40	$ 1,500
		1/2T-Pickup		hour	$ 7	40	$ 261
		2-Flatbed Trucks		hour	$ 19	80	$ 1,500
Decontamination/Decommissioning (WBS 33.1.17)							$ 6,734
Release of Equipment							*$ 6,734*
	VACIS Super			hour	$ 61	8	$ 490
	VACIS Tech 1			hour	$ 48	8	$ 388
	VACIS Tech 2			hour	$ 48	8	$ 388
			Per diem	day	$ 100	3	$ 300
	Site Health Physics Super.			hour	$ 80	8	$ 644
	Site H&S Staff			hour	$ 71	8	$ 570
	Site Coordinator			hour	$ 90	8	$ 717
	Site Radiation Control Tech.			hour	$ 48	8	$ 388
	Site Equipment Operators			hour	$ 58	24	$ 1,398
		VACIS Unit		hour	$ 100	8	$ 801
		Forklift - 8 ton		hour	$ 38	8	$ 300
		1/2T-Pickup		hour	$ 7	8	$ 52
		Flatbed Truck		hour	$ 19	16	$ 300
Demobilization (WBS 33.1.21)							$ 2,948
Demobilize Equipment							*$ 1,067*
		VACIS Unit		hour	$ 100	10	$ 1,001
		1/2T-Pickup		hour	$ 7	10	$ 65
Demobilize Personnel							*$ 1,882*
	VACIS Super			hour	$ 61	10	$ 613
	VACIS Tech 1			hour	$ 48	10	$ 485
	VACIS Tech 2			hour	$ 48	10	$ 485
			Per diem	day	$ 100	3	$ 300

Figure B-1 Implementation Cost Detail

APPENDIX D
ACRONYMS AND ABBREVIATIONS

Ci	Curie
DOE	U.S. Department of Energy
D&D	Decontamination and Decommissioning
DDFA	Deactivation and Decommissioning Focus Area
DVRS	Decontamination and Volume Reduction System
G&A	General and Administrative
FRP	fiberglass reinforced plywood
GSA	General Services Administration
HTRW RA WBS	Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure
ICT	Integrating Contractor Team
LANL	Los Alamos National Laboratory
LSDDP	Large-Scale Demonstration and Deployment Project
MCS	Mobile Characterization Services
NETL	National Energy Technology Laboratory
OMB	Office of Management and Budget
OST	Office of Science and Technology
PPE	Personal Protective Equipment
RCRA	Resource Conservation and Recovery Act
RCT	Radiation control technicians
RMA	Radioactive Material Area
SAIC	Science Applications International Corporation
SWB	standard waste boxes
TLD	Thermo luminescent detector
TMEC	US Army's Thunder Mountain Test and Evaluation Center
TMS	Technology Management System
TRU	transuranic
US	United States
VACIS™	Vehicle and Cargo Inspection System
WBS	work breakdown structure
WIPP	Waste Isolation Pilot Plant